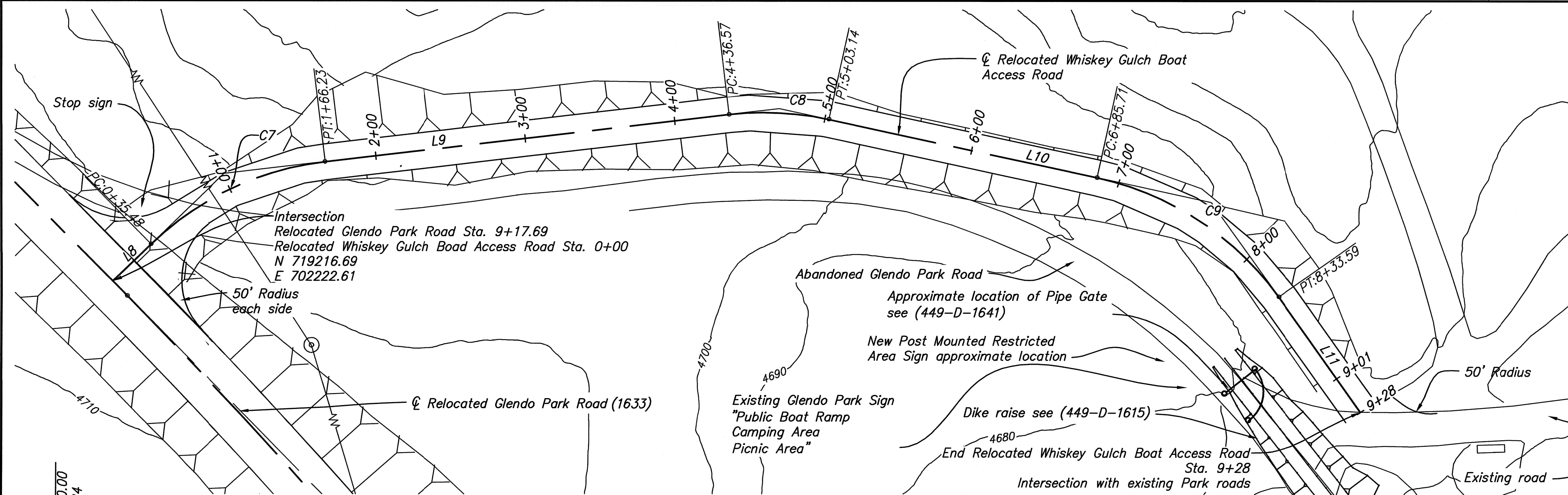
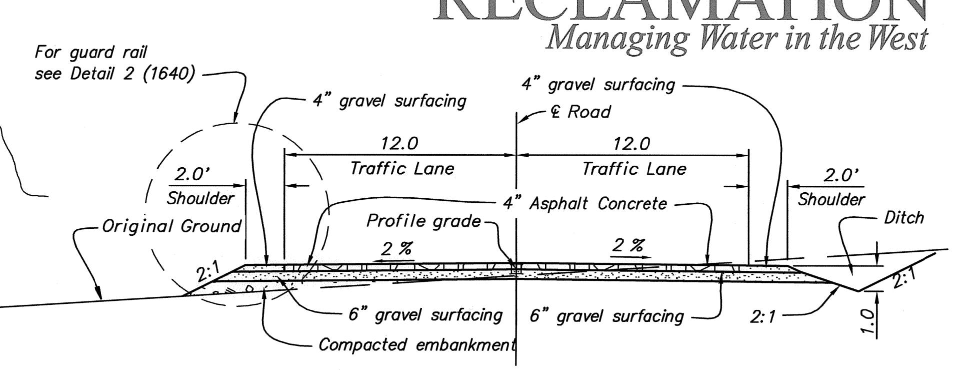
RECLAMATION
Managing Water in the West



PLAN

SCALE OF FEET



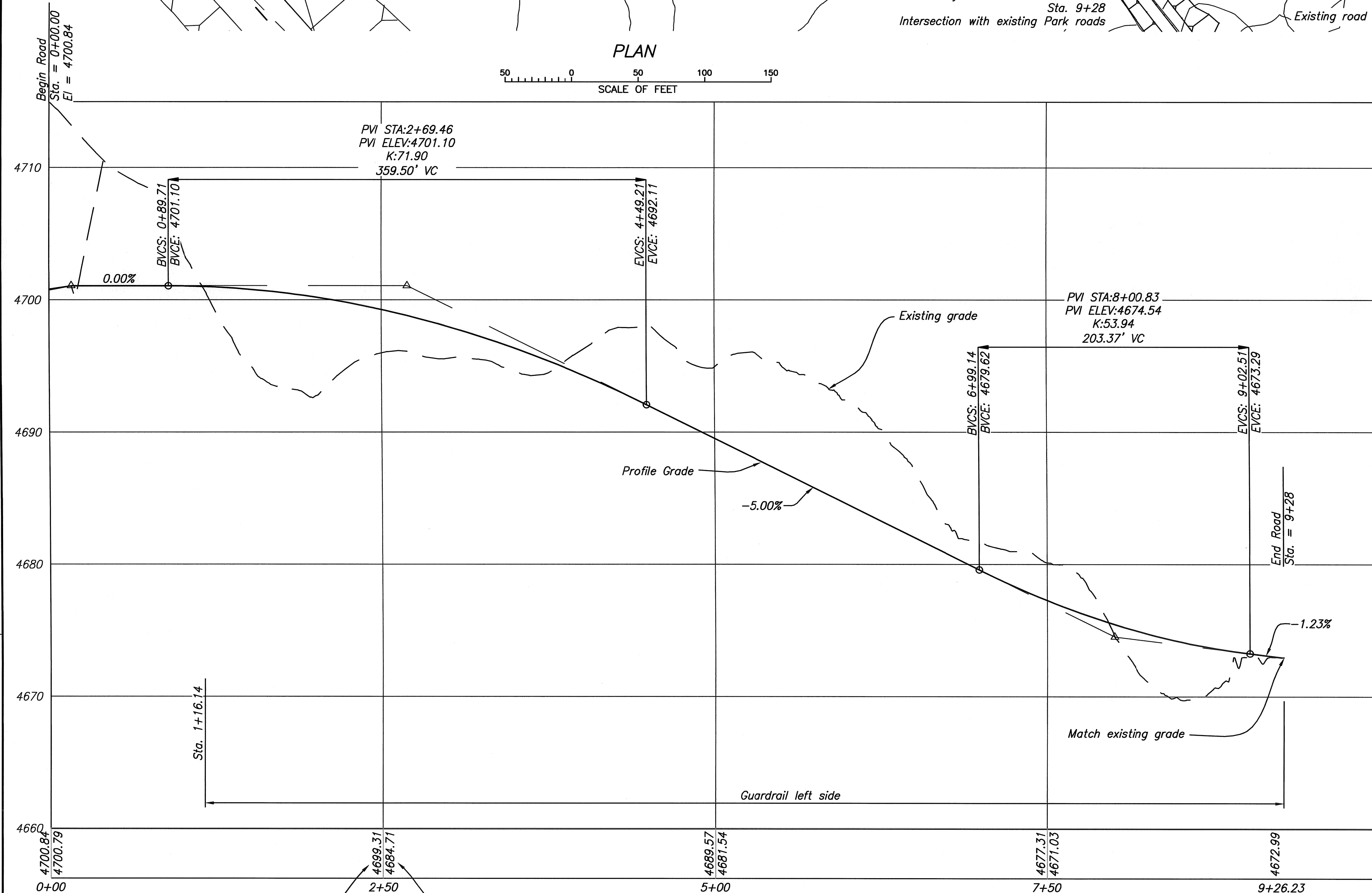
TYPICAL SECTION

Relocated Whiskey Gulch Boat Access Road

SCALE OF FEET

Curve Table								
Curve	Length	Radius	Delta	Tangent	Chord	PI	PC	PT
C7	130.75	200.06	37°26'43"	67.80	128.43	1+03.29	0+35.48	1+66.23
C8	66.57	200.06	19°04'00"	33.60	66.27	4+70.17	4+36.57	5+03.14
C9	147.88	200.06	42°21'07"	77.50	144.53	7+63.21	6+85.71	8+33.59

Line Table							
Line #	Length	Bearing	Start Northing	Start Easting	End Northing	End Easting
L8	35.48	N45° 48' 12.55"E	719216.69	702222.61	719241.41	702248.05
L9	270.34	N83° 14' 55.33"E	719296.64	702363.96	719328.41	702632.35
L10	182.57	S77° 41' 04.81"E	719325.19	702698.52	719286.26	702876.83
L11	94.51	S35° 19' 57.57"E	719206.53	702997.34	719129.45	703051.98



PROFILE

NOTES

1. General Notes, and Abbreviations refer to 449-D-1640.
2. Existing road grades and locations are estimates and should be field verified
3. Design Speed 15mph
4. The 1983 North American DATUM (NAD 83) and the 1929 National Geodetic Vertical Datum (NGVD 29) are the horizontal and vertical datum utilized on all drawings associated with the Glendo Dam modification. All topography, coordinates, and elevations shown are in grid Wyoming State Plane Coordinate System, Wyoming East Zone, U.S. Survey Feet, NAD 83 Horizontal Datum and NGVD 29 Vertical Datum. The topography was generated from aerial photography dated May 16, 2006. Combined Scale Factor = 0.99971591
Grid to Ground = 1.000284171
All dimensions and stationing are ground distances.

REV NO	Date / By	Description
2	10-07-23 D - Mark Leavitt, PE MARK LEAVITT, PE	ADDED STOP SIGN GENERAL LOCATION. ADDED EXISTING PARK SIGN GENERAL LOCATION.
1	10-07-16 D - MARK LEAVITT, PE	ADDED NOTE 4. OTHER MINOR CHANGES.

ALWAYS THINK SAFETY

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
PICK - SLOAN MISSOURI BASIN PROGRAM
OREGON TRAIL DIVISION - GLENDO UNIT - WYOMING

GLENDO DAM MODIFICATION

RELOCATED WHISKEY GULCH BOAT ACCESS ROAD
PLAN AND PROFILE
STA. 00+00 TO END

DESIGNED JOE M. GEMPERLINE CHECKED MARK LEAVITT
DRAWN JOE M. GEMPERLINE TECH. APPR. MARK LEAVITT, P.E.
MARK LEAVITT, P.E.
APPROVED DAVID K. EDWARDS, P.E.
DAVID K. EDWARDS, MANAGER, WATER CONVEYANCE GROUP

DENVER, COLORADO 2010-04-07 SHEET 1 OF 1 449-D-1638

CAD SYSTEM
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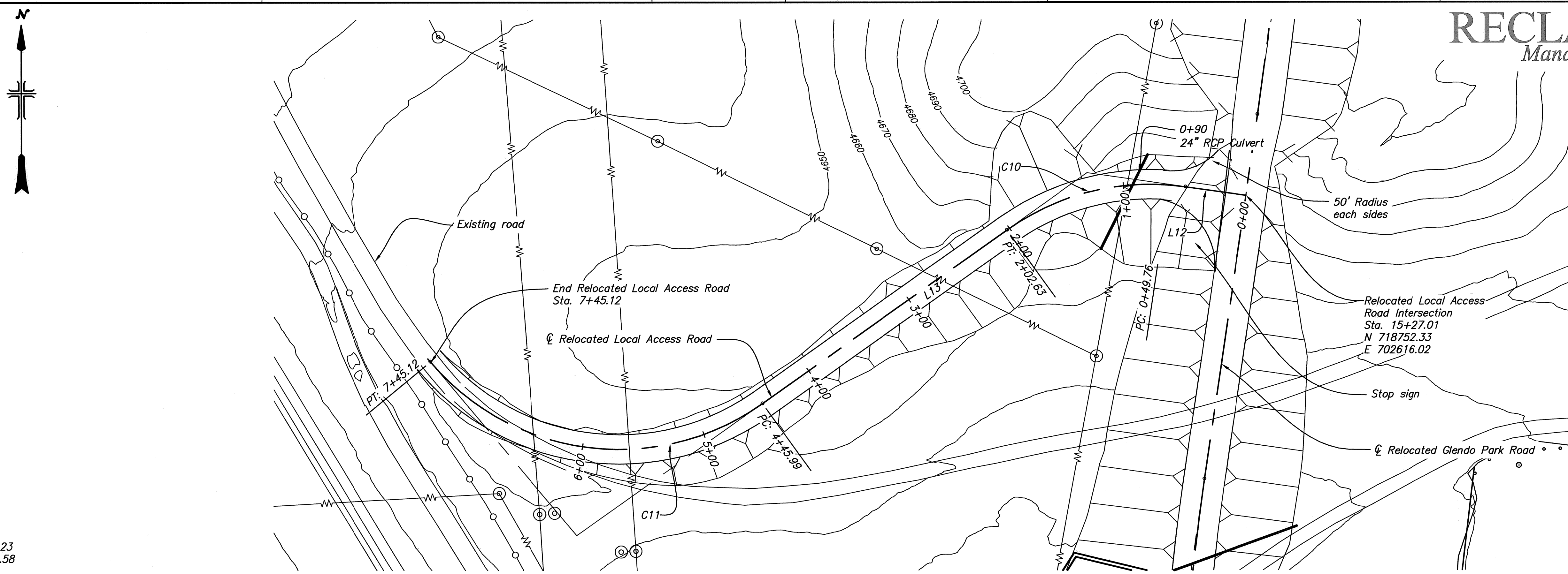
RECLAMATION
Managing Water in the West



PLAN

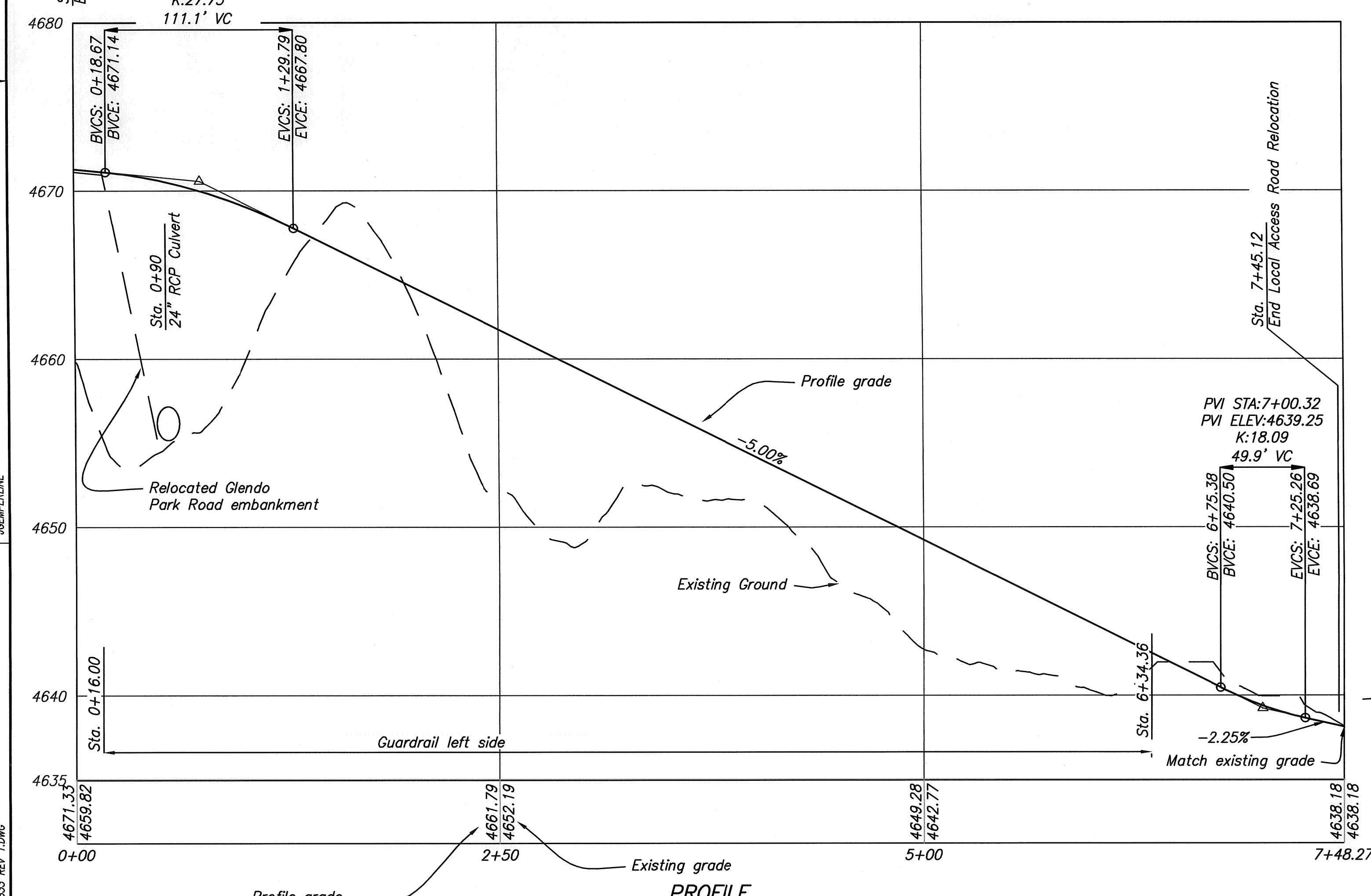
SCALE OF FEET

Line Table						
Line #	Length	Bearing	Start Northing	Start Easting	End Northing	End Easting
L12	49.77	S53° 10' 58.43"W	718752.33	702616.02	718722.51	702576.18
L13	243.43	S9° 23' 11.99"W	718595.02	702498.72	718354.92	702459.02

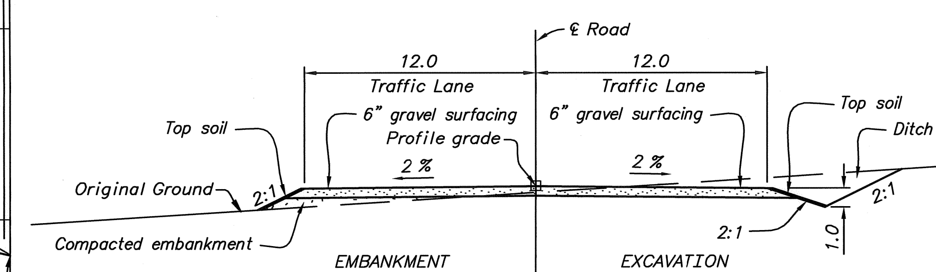
Curve Table								
Curve	Length	Radius	Delta	Tangent	Chord	PI	PC	PT
C10	152.92	200.06	43°47'46"	80.41	149.23	1+30.18	0+49.77	2+02.69
C11	299.22	200.06	85°41'43"	185.56	272.10	6+31.68	4+46.12	7+45.34

NOTES

1. General Notes, and Abbreviations refer to 449–D–1640.
2. Existing road grades and locations are estimates and should be field verified
3. Design Speed 15mph
4. The 1983 North American DATUM (NAD 83) and the 1929 National Geodetic Vertical Datum (NGVD 29) are the horizontal and vertical datum utilized on all drawings associated with the Glendo Dam modification. All topography, coordinates, and elevations shown are in grid Wyoming State Plane Coordinate System, Wyoming East Zone, U.S. Survey Feet, NAD 83 Horizontal Datum and NGVD 29 Vertical Datum. The topography was generated from aerial photography dated May 16, 2006. Combined Scale Factor = 0.99971591 Grid to Ground = 1.000284171 All dimensions and stationing are ground distances.



PROFILE



TYPICAL SECTION

RELOCATED LOCAL ACCESS ROAD

SCALE OF FEET

REV NO	Date / By	Description
2	10–07–23 D – MARK LEAVITT, PE	ADDED STOP SIGN GENERAL LOCATION.
1	10–07–16 D – MARK LEAVITT, PE	ADDED NOTE 4. OTHER MINOR CHANGES.

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UNITED STATES
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PICK – SLOAN MISSOURI BASIN PROGRAM
OREGON TRAIL DIVISION – GLENDO UNIT – WYOMING

GLENDO DAM MODIFICATION
RELOCATED LOCAL ACCESS ROAD
PLAN AND PROFILE
STA. 0+00 TO END

DESIGNED JOE M. GEMPERLINE CHECKED MARK LEAVITT
DRAWN JOE M. GEMPERLINE TECH. APPR. MARK LEAVITT, P.E.
APPROVED DAVID K. EDWARDS, P.E.
DAVID K. EDWARDS, MANAGER, WATER CONVEYANCE GROUP

DENVER, COLORADO 2010–04–07
SHEET 1 OF 1

449–D–1639

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DIVISION 53 – GEOLOGIC INVESTIGATIONS AND RECORDS

SECTION 53 10 00

GEOLOGIC INVESTIGATIONS

PART 1 GENERAL

1.01 GENERAL

A. General

1. The geologic descriptions, drawings, logs of subsurface explorations, water level data, and test data in these specifications include information and records of geologic investigations for the work, and are the geologic data upon which the design of this work is based. These data supersede any previous versions which may be available for examination by offerors. Only the data that are specific to the needs of these specifications are included in these specifications. These data are contained in Section 53 20 00 - Records of Geologic and Subsurface Investigations.

2. Geologic drawings and sections and records of previous investigations that have relevance for this work are included under Informational Drawings.

3. Selected samples recovered during investigations were tested by the Bureau of Reclamation's (Reclamation) Materials Engineering and Research laboratories in Denver, Colorado and Reclamation's Construction Services Laboratory in Loveland, Colorado. Summaries of Physical Properties Test Results from laboratory tests performed on these samples are contained in Section 53 20 00 - Records of Geologic and Subsurface Investigations. Samples of drill core and samples collected for the borrow area investigations are available for examination at Reclamation's Materials Engineering and Research laboratories in Denver, Colorado. Offerors wishing to inspect the samples should make arrangements with the CO. Offerors are encouraged to inspect the site and to obtain their own samples and perform tests on the materials to evaluate properties which the offeror believes to be significant. Offerors wishing to take samples at the site should make arrangements with the Contracting Officer.

4. Copies of the following reports and memoranda which contain pertinent information on the area, site geology, and materials properties may be examined at the Bureau of Reclamation, Wyoming Area Office, Mills, WY. Offerors wishing to inspect the reports and memoranda should make arrangements with the CO.

   a. Baker, Kari, Report on the Geologic Investigation for Glendo Dikes, Wyoming, Pick-Sloan Missouri Basin Project, U.S. Department of the Interior, Bureau of Reclamation, Great Plains Region, May 2009.

b. Baker, Kari, Glendo Dam, Safety of Dams Modifications, Borrow Investigation for Final Design, Pick-Sloan Missouri Basin Project, Wyoming, U.S Department of the Interior, Bureau of Reclamation, Great Plains Region, Geology and Exploration Services, February 2009.

c. Birch, R.O., Geology Report Glendo Dam Site., U.S Department of the Interior Bureau of Reclamation, 1951.

d. Bureau of Reclamation, Laboratory Soil Tests Made in the Preliminary Investigation of Proposed Borrow Areas for Glendo Dam, Earth Materials Laboratory Report No. EM-156, Glendo Unit, Missouri River Basin Project, Wyoming, U.S Department of the Interior, Bureau of Reclamation, Research and Geology Division, Branch of Design and Construction, Denver, Colorado, January 13, 1948.

e. Bureau of Reclamation, Supplemental Report on Laboratory Soil Tests Made on Proposed Embankment Materials for Glendo Dam, Earth Materials Laboratory Report No. EM-201, Glendo Unit, Missouri River Basin Project, Wyoming, U.S Department of the Interior, Bureau of Reclamation, Research and Geology Division, Branch of Design and Construction, Denver, Colorado, March 31, 1949.

f. Bureau of Reclamation, Laboratory Investigations of Concrete Aggregate and Riprap, Glendo Dam, Materials Laboratories Report No. C-464, Glendo Unit, Missouri River Basin Project, Wyoming, U.S Department of the Interior, Bureau of Reclamation, Research and Geology Division, Branch of Design and Construction, Denver, Colorado, October 27, 1949.

g. Bureau of Reclamation, Final Construction Report, Glendo Dam and Powerplant, Glendo Unit, Oregon Trail Division, Missouri River Basin Project, U.S Department of the Interior, Bureau of Reclamation, June 1960.

h. Bureau of Reclamation, Glendo Dam and Powerplant, Technical Report of Design and Construction, Missouri River Basin Project, Glendo Unit-Wyoming, U.S Department of the Interior , Bureau of Reclamation, July 1961.

i. Bureau of Reclamation, Technical Record of Construction, Glendo Dikes Seepage Berms, Contract/Specifications 9-CC-60-03620/DC-7775, Pick-Sloan Missouri Basin Project, Glendo Unit- Wyoming, U.S. Department of the Interior, Mills, Wyoming, January 1992.

j. Dirmeyer, R.D., Geology Report. Glendo Dam and Reservoir Site, Missouri Basin Project, U.S Department of the Interior, Bureau of Reclamation, February 1948.

k. Dirmeyer, R.D., Geology Report (Reconnaissance), Sediment Source Survey Glendo Drainage Area, Wyoming., U.S. Department of the Interior Bureau of Reclamation, 1950.

l. Erdogan, Zeynep, Results of Laboratory Physical and Mechanical Properties Tests for the Proposed Auxiliary Spillway Investigation, Technical Memorandum No. MERL-07-19, Glendo Dam, Pick-Sloan Missouri Basin Project, Wyoming, U.S Department of the Interior, Bureau of Reclamation, Technical Service Center, Materials Engineering and Research Laboratory, Denver, Colorado, October 2007.

m. Heisler, R., Test Trench TT06-1 Geology and Erodibility Index of the Brule Formation, Glendo Dam, Corrective Action Alternative Study, U.S Department of the Interior Bureau of Reclamation, Technical Service Center, Denver, Colorado, January 2007.

n. McDonough, Dennis, Construction Materials Design Data Report for Glendo Dikes Seepage Control, Glendo Dam, Glendo Unit, Oregon Trail Division, Wyoming, Pick-Sloan Missouri Basing Program., U.S. Department of the Interior, Bureau of Reclamation, Great Plains Regional Office, September 1986.

o. McDonough, Dennis, 1987-1988 SEED Investigation of Glendo Dam, Glendo Unit, Oregon Trail Division, Wyoming, Pick-Sloan Missouri Basing Program., U.S. Department of the Interior, Bureau of Reclamation, Great Plains Regional Office, October 1988.

p. Parish, Lovell, Geologic Design Data Report for the Seepage Control Modification of Glendo Dikes, Oregon Trail Division, Glendo Unit, Wyoming, U.S Department of the Interior, Bureau of Reclamation, Missouri Basin Region, 1988.

q. Robb, George L., Geology Report, Glendo Damsite and Reservoir, Missouri Basin Project, Wyoming, U.S. Department of the Interior, Bureau of Reclamation, Region VII, Denver, Colorado, September 3, 1946.

r. Star, Murel M., Preliminary Earth Materials Investigation Report, Glendo Dam, Glendo Unit, Missouri River Basin Project, Wyoming, U.S Department of the Interior, Bureau of Reclamation, Glendo, Wyoming, August 11, 1948.

s. Taucher, G., Geologic Design Data Report, Glendo Dam Low Flow Outlet Works Oregon Trail Division, Glendo Unit Wyoming., U.S. Department of the Interior, Bureau of Reclamation, September 1991.

t. Strauss, Thomas, Results of Laboratory Studies of Potential Borrow Source Materials and Soil Cement Mix Design – Glendo Auxiliary Spillway Modification, Pick-Sloan Missouri Basin Program, Wyoming, Materials Engineering and Research Laboratory (MERL) Referral Number: MERL-10-09, Bureau of Reclamation, Technical Service Center, materials Engineering and Research Laboratory Group, Denver, Colorado, April 26, 2010.

u. Hurcomb, Doug, Visual Petrographic Examination of Rock Samples for Use as Riprap, Glendo Dam Modification, Glendo Unit, Pick-Sloan Missouri Basin Program, WY, MERL 8180-10-5, Petrographic Referral code: 2010-3, Bureau of Reclamation, Technical Service Center, Materials Engineering and Research Laboratory Group, Denver, Colorado, February 17, 2010.

v. Madera, Veronica, Physical Properties of Potential Riprap Sources for Glendo Dam Modification, MERL 2010-11, Bureau of Reclamation, Technical Service Center, Materials Engineering and Research Laboratory Group, Denver, Colorado, May 21, 2010.

5. The geologic logs of drill holes, test pits, test trenches, water-level data, and other available geologic information indicate the conditions encountered during the investigations. The water-level data show the conditions at the particular time or times the information was obtained and may not indicate variations such as those caused by drought, precipitation, changes in the surface elevation of nearby reservoirs, irrigation or flooding.

6. The geologic drawings portray generalized geologic conditions. The geologic logs of explorations should be consulted for specific details. Engineering geology and geotechnical considerations are discussed in Engineering Geology and Geotechnical Considerations article. For a discussion of water occurrence, see Engineering Geology and Geotechnical Considerations article. For General Geologic Legend, Explanation, and Notes, refer to drawing number 449-600-584.

7. General geologic unit definitions, explanations of geologic symbols, and geologic notes are shown on drawing number 449-600-584.

8. Surface geology and location of explorations, cross sections, and note drawings for the work are included in these specifications on Drawing Nos. 449-600-584, 449-D-1644 through -1649. Cross sections of the dam abutments and dike 1 right abutment are shown on geologic overlays on design drawings 449-D-1612, -1613, and -1616. Locations of borrow areas, explorations, and geologic sections are shown on Drawing Nos. 449-600-583, and -585 through -588.

9. Surficial materials recorded in all geologic exploration logs included in these Specifications were classified under current Unified Soil Classification System procedures as described in USBR 5000 (laboratory classification) and USBR 5005 (visual classification). These two procedures are similar to ASTM D 2487 and ASTM D 2488, respectively. Surficial materials recorded on geologic exploration logs prepared before January 1, 1986 were described using the terminology on Reclamation Standard Drawing 103-D-347. Copies of the above Reclamation procedures are available for review at the Bureau of Reclamation, Technical Service Center, Denver, Colorado.

10. Reclamation has established standard descriptors and descriptive criteria for rock and standard descriptors and descriptive criteria for discontinuities. These standards are shown on drawings 40-D-7022 and 40-D-7023. The standards

provide the basis for classification and description of rock and discontinuities logged after September 1984.

1.02 REFERENCE STANDARDS

A. ASTM International (ATSM)

1. ASTM D 2487-06 Classification of Soils for Engineering Purposes (Unified Soil Classification)
2. ASTM D 2488-06 Description and Identification of Soils (Visual-Manual Procedure)

B. Bureau of Reclamation (USBR)

1. USBR EM – Earth Manual, Part 2, Third Edition (1990)
2. Procedure No. and Title
   a. USBR 5000-86 Determining Unified Soil Classification (Laboratory Method)
   b. USBR 5005-86 Determining Unified Soil Classification (Visual Method)

1.03 GEOLOGIC INVESTIGATIONS

A. Geologic investigations conducted at Glendo Dam and Dikes are listed below; and available logs of investigations are contained in Section 53 20 00 - Records of Geologic and Subsurface Investigations.

B. Previous Investigations: Previous investigations at Glendo Dam and Dikes include preconstruction investigations conducted from about 1946 to about 1956. Preconstruction geologic investigations for modifications to Glendo Dikes began after 1971 and continued until the dikes were modified in 1989. Modification Decision Analysis (MDA) investigations were completed in 1987 and 1988. In 1991, geologic design data was obtained for the Low Flow Outlet Works. Previous investigations are summarized below.

1. Preconstruction investigations to determine the extent and physical properties of foundation materials at the dam consisted of diamond drill holes, DH201, DH202 and DH202A, DH203 through DH213, four test trenches, Trench No. 1 through No. 4.
2. Preconstruction investigations to determine the extent and physical properties of foundation materials at the dikes and to determine the seepage potential through the natural ridge that forms the south reservoir rim consisted of 15 diamond drill holes, DH1 through DH6, DH7W and DH7E, DH8, DH9E and DH9W, DH10, DH11E and DH11W, and DH12; and two test pits, TP8 and TP10. Downhole permeability tests at that time indicated that the Brule Formation (Tb) materials

that form the ridge are relatively impervious below an elevation of 4655 feet. Downhole packer permeability tests were conducted with pressures of 100 psi from depths of 10 feet. Such high pressures would not be used near the ground surface today and such pressure may have hydrofractured the Brule Formation (Tb) locally. Hydraulic conductivities in DH10 located near the west end of the proposed auxiliary spillway ranged from 0 feet per year near the bottom of the hole (elevation 4634.5 to 4624.5) to an average of about 430 feet per year from 10 to 30 feet depth (elevation 4695.4 to 4675.4).

3. In 1973 and 1974 a grouting program was completed in the abutments of all three dikes to control excessive seepage through the fractured bedrock foundation. Detailed geologic logs were prepared for seven holes. Following the grouting program seepage conditions continued and were present during high reservoir levels.

4. Reference p under General article summarizes the following investigations that were completed from 1984 to 1988.

    a. In 1984, nine drill holes, DHP1B and DHP2 through DHP9 were completed at the downstream toe of the dikes to monitor water levels. Two porous tube piezometers per hole were installed and designated PTP-1A and-1B through PTP-9A and -9B. These installations will need to be protected during construction as described in Section 31 09 22 – Protecting and Extending Existing Piezometers. Details of the investigation are in reference 16.

    b. In 1984, three test pits, TPP1 through TPP3, one at the downstream toe of each dike, were excavated to obtain information on the character and jointing of the bedrock foundation. Details of the investigation are in reference 16.

    c. In 1986, a construction materials investigation was completed to find suitable pervious material for anticipated dike modifications. Test Pits TP86-1 through TP86-22 were excavated for this effort. The borrow area was located immediately west of Dike 1 and consisted of terrace alluvium and loess deposits overlying the Brule Formation (Tb) bedrock. Explorations in the borrow area indicated that the materials were variable in nature and texture and contained variable amounts of moisture and plus 5-inch material. Details of the investigation are in reference 14.

    d. In 1987, two test pits, TP87-1 and TP87-2, were completed at the downstream toe of Dike 3 to determine the character of the fill in the abandoned railroad cut. Details of the investigation are in reference 16.

    e. In late 1987 and 1988, three SPT drill holes, PR87-1, PR88-2 and PR88-3 were completed in the main dam to depths of 66.3, 68.0, and 192.3 feet, respectively. PR88-3 was drilled from the dam crest. PR87-1 and -88-2 were drilled from the downstream face of the dam. Two porous tube piezometers were installed in each drill hole. The holes were drilled through the embankment and into the Quaternary sediments beneath the dam to bedrock to provide data for the MDA. Uncorrected blow counts in the zone 1 embankment were greater than 50; in the zone 2 embankment ranged from 12 to greater than 50, and in the zone 3 embankment ranged from 20 to greater than 50. Uncorrected blow counts in the Loess ranged from 9 to greater than 50 and in the alluvium from 27 to greater than 50. Details of the investigation are in reference 16.

f. In 1988, geologic design data was obtained for the seepage control modification of Glendo Dikes. Twenty test pits, TP88-1 through TP88-20, were excavated to determine the depth and properties of material overlying the bedrock, and the properties and jointing characteristics of the upper part of the bedrock unit. Geologic mapping of the dike area including a joint survey was completed and samples obtained from the Brule Formation (Tb) for Petrographic examination. Details of the investigation are in reference 16.

1) Observations during this investigation indicated the Brule Formation (Tb) is mottled with light green material and contains siltstone dikes comprised of the green material. Petrographic examination of a sample of the green material obtained during the 1988 field mapping indicated that the green material consists of 60 to 65 percent smectite, which was chiefly calcium-montmorillonite, 10 to 15 percent volcanic glass, and 5 percent or less of calcite, quartz, illite/mica, feldspar, and minor minerals.

2) Petrographic examination of a representative rock fragment of the Brule Formation obtained during the 1988 field mapping indicated that the rock is composed of 25 to 30 percent calcium-montmorillonite, 20 to 25 percent volcanic glass, 15 percent calcite, 10 to 15 percent quartz, 5 to 10 percent illite/mica, 5 percent feldspar, and 10 percent minor and accessory minerals. The presence of calcium-montmorillonite, a major component of bentonite derived from insitu weathering of volcanic ash.

3) Three test pits, TP88-11, -12, and -13 were excavated into the buried channel materials. Laboratory classifications of these materials from TP88-11 and -12 were clayey silt (CL-ML) with average fines content of 80 percent and 20 percent sand. Both samples had a LL = 29 and PI = 5. Inplace densities were obtained with 80.4 lb/ft^3 at 12.1 percent moisture and 85 flb/ft3 at 8.5 percent moisture with optimum unit weights of 100.6 lb/ft^3 at 14.5 percent moisture and 102.6 lb/ft^3 at 16.7 percent moisture respectively**.**

5. In 1991, geologic design data was obtained for a proposed low flow outlet works. Three cored drill holes, DH91-1 through DH91-3 were completed along the outlet works alignment, including point load testing of drill core samples, and geologic

mapping. During drilling, fluid losses were noted in drill holes DH91-1 and DH91-2. These losses are believed to have occurred in open fractures in the Morrison Formation. Details of the investigation are in references.

C. Current Investigations: Geologic investigations for the Corrective Action Alternatives Study and for Final Design for the Glendo Dam Modifications were conducted from October, 2006 to November, 2009. These investigations consist of test trenches, drill holes, and test pits for design data and foundation materials testing as well as test pits for borrow investigations. Borrow Investigations and Materials are discussed under Borrow Investigations article.

1. Test Trench TT-06-1 was completed downstream of the auxiliary spillway. The purpose of the trench was to geologically map fresh Brule Formation bedrock to provide data for an erodibility assessment and to provide foundation characteristics for the auxiliary spillway. TT-06-1 was excavated to a total depth of about 8 feet. The trench measured approximately 100 feet long from upslope to downslope by 80 feet wide parallel to the slope. TT-06-1 was left open to conduct jet erosion tests to determine erodibility and to observe the degradation of the Brule Formation; the trench remains open to date. Details of the TT-06-1 excavation and geology and a short video clip of the trench excavation in Brule Formation are included in reference 13. The trench excavation and geology are summarized below.

a. Equipment used included a Caterpillar (CAT) D7 dozer with one ripper tooth, a CAT 950F front end loader, and a Link-Belt 210LX Excavator with a bar over the teeth to facilitate a smooth excavation surface. Equipment travel by the CAT D7 dozer expedited slaking and spalling of the Brule Formation (Tb). The upper approximately 1/2-inch of the Brule Formation slaked and spalled into thin sheets that curled up as they dried out. The trench was cleaned using a Sullair Air compressor. The method of excavation and cleanup resulted in an excellent exposure.

b. A pre-trench excavation test pit was completed with a Link Belt excavator with bar over teeth near the top of the final trench excavation site to determine the approximate depth to bedrock and the quality of the rock that could be excavated using the excavator. The test pit was excavated to a depth of about 4 feet where the excavator met refusal in moderately weathered and moderately fractured rock. Although the very intensely weathered and very intensely fractured rock and overlying colluvium were easily excavated with the excavator, the use of the dozer with ripper tooth was required to excavate to fresh, slightly fractured rock.

c. Brule Formation (Tb) exposed in the excavation of TT-06-1 consists of tan to light gray, moderately soft to soft, fine-grained sedimentary rock which ranges from clayey siltstone to local fine silty sandstone. Tb in TT-06-1 is laminated to thickly bedded (most beds range from about 1/2-inch to 2 feet thick). Bedding consists of alternating mostly thin (3/8-inch to 1-inch thick) horizontally bedded zones with mostly moderately thick (about one foot thick) lenticular bedded zones. The thin beds are highly continuous, horizontal, and planar. The lenticular beds are moderately continuous for about 30 feet and dip up to about 20 degrees both upstream (north) and downstream (south).

d. The dominant structure in the Brule Formation is highly continuous subhorizontal bedding. When combined with mostly widely to very widely spaced near-vertical joints (average spacing 2 to 4 feet apart), the bedding could result in slab-shaped blocks on the order of 2 by 4 by 1 foot thick. However, it appears that the low strength of the Brule Formation dominates the block size such that smaller blocks, 1-foot in size or less could be expected. During excavation of the test trench, the rock developed incipient fractures either due to the weight of the equipment or to slaking and broke along incipient fractures, creating blocks mostly 1-foot in size or less.

e. Discontinuous incipient fractures, less than two feet long were observed on the surface of the Brule Formation in TT-06-1. These fractures are interpreted to be due to slaking and are probably not primary discontinuities in the rock mass. However, if the Brule Formation surface is not protected from slaking, these fractures would be expected to form and result in further weakening of the rock mass.

f. Throughout the trench exposure, the Brule Formation (Tb) contains veins, stringers, lenses and patches of green clay, clayey siltstone, and claystone. The green material is also present along many joints where it appears as a discoloration or alteration on either side of the joint as well as joint filling. These variations in composition and color are consistent with those noted during geologic mapping at the dikes in 1988.

g. <u>Slaking</u>. The slaking behavior of the Brule Formation was observed during the excavation of the test trench (October 2 – 4, 2006) and two subsequent site visits on October 12, 2006 and on October 16, 2006. Slake tests were conducted on samples collected from the test trench.

1) During the excavation of TT-06-1, a sample of the Brule Formation developed hairline to slightly open fractures within minutes of being exposed.

2) About one week after the Brule Formation (Tb) foundation in the test trench had been cleaned with air, the Brule Formation (Tb) had slaked considerably. Slaking had occurred in the upper approximately one-half inch of the surface. Numerous hairline fractures had developed as well as separation along fractures.

3) About two weeks after exposure of the test trench, considerable slaking of the Brule Formation had occurred since the prior week due to recent rainfall and presumably repeated wetting and drying.

4) Slake tests were conducted on two samples of the Brule Formation (Tb). One was allowed to dry out for about two weeks and the other was wrapped in plastic wrap and freezer bags to retain natural moisture.

a) The air dried sample completely slaked when immersed in water. The initial reaction was slow, with small flakes of material sloughing off of the sample but, at about 4 minutes after immersion in tap water, the sample developed a crack that bisected the sample, and slaking was rapid after that. After about 30 minutes, the volume change was intense and about 95 percent of the volume of material had slaked. Thus the rate of slaking of the air dried sample was rapid to moderate. The material remaining after slaking consisted of mostly flakes and plates with about 20 percent clay-size particles.

b) The sample at natural moisture experienced slight to no discernable disaggregation when immersed in tap water after one week.

h. Dispersive Characteristics. Because of the presence of bentonite, the Brule Formation was field tested for dispersion. Crumb tests were conducted on several samples of the Brule Formation obtained from TT-06-1 using tap water. Tests were conducted on intact Brule at natural moisture and on moist cubes that were remolded from air dried samples that had been manually disaggregated. The reaction of all of the samples was Grade 1, no reaction, indicating the Brule Formation is nondispersive.

2. Drill holes DH07-1 through DH07-5 were completed at the auxiliary spillway site and at the dikes. Drill holes DH07-1 and DH07-5 provided rock cores from the Brule Formation (Tb) at the proposed auxiliary spillway site. Drill holes DH07-2, -3, and -4 were drilled in Dikes 1, 2, and 3 respectively. Except for Drill Hole DH07-1 which was drilled 60 degrees from horizontal at a bearing of S35°W, all drill holes were drilled vertically. Downhole permeability testing was performed in the rock portions of the drill holes. The dike drill holes provided rock and dike embankment cores. All of the drill holes were completed with porous tube piezometers to track water levels at the dikes and the auxiliary spillway site. In addition, the dikes drill holes were completed with vibrating wire piezometers. The porous tube piezometers at the auxiliary spillway site are designated PTP07-1 and PTP07-2 for piezometers installed in drill holes DH07-1 and DH07-5 respectively. The dikes vibrating wire piezometers are designated VW07-1, VW07-2, and VW07-3 for vibrating wires installed in DH07-2, -3, and -4 respectively. The investigations are summarized below and detailed in reference a.

a. Auxiliary Spillway Drill Holes: DH07-1 and DH07-5 were drilled just south of the existing dam access road. Both drill holes encountered Tb from the ground surface. Drill hole DH07-1 was drilled to a depth of 130.0 feet and drill hole DH07-5 was drilled to a depth of 117.6 feet. Drill core consists of massive siltstone with green bentonitic clay as patches and filling local fractures. Moderately hard to hard and moderately weathered to fresh Tb was encountered in both drill holes. The bentonitic clay is very soft to moderately soft with medium to high plasticity and 10 percent or less sand. In general, the rock is intensely to moderately fractured to depths of about 55 feet; moderately fractured to unfractured below about 55 feet. These depths generally correspond to permeability test results: below about 56 feet the hydraulic conductivities were 0. One local zone of intensely fractured rock was encountered in DH07-1 from 92.9 to 94.5 feet. Fracture densities and permeability values are shown on drawings 449-D-1645 and 449-D-1647.

b. In DH07-1, permeability tests were conducted from 14 feet to the bottom of the hole. Gravity tests were conducted from 14 to 36 feet and from 46 to 56 feet; cyclic stepped pressure tests were conducted from 36 to 46 feet and from 56 feet to the bottom of the hole in 10 foot lengths using packers with applied pressures of up to 15 psi. Hydraulic conductivities in the upper 56 feet of the drill hole (to elevation 4650.4) ranged from about 6 to 184 feet per year. The highest value of 184 feet per year occurred between the depths of 46 to 56 feet in an intensely fractured zone. Below a depth of 56 feet, hydraulic conductivities were 0 feet per year.

c. In DH07-5, permeability tests were conducted from a depth of 9.0 feet to the bottom of the drill hole, except between depths of 29 and 50 feet where a packer could not be seated due to the presence of a fracture zone from 35.2 to 40.0 feet. Gravity tests from 9 feet to 29 feet resulted in hydraulic conductivities of 23 to 31 feet per year. Below a depth of 50 feet, hydraulic conductivities were 0 feet per year.

d. Rock core samples of the Brule Formation (Tb) obtained from drill holes DH07-1 and DH07-5 at the auxiliary spillway site were tested for physical properties, uniaxial compression, and direct shear strengths. The testing program consisted of 5 uniaxial compressive strength and 6 direct shear tests. In addition, 5 physical properties test suites were completed on end pieces from the uniaxial test specimens and two of the direct shear test specimens.

1) Tested samples moisture contents ranged from 18 to 23 percent. Dry unit weights ranged from 98 to 110 lb/ft^3 with an average of 105.2 lb/ft^3. Apparent specific gravities varied from 2.38 to 2.61 with a median value of 2.47 and average of 2.48. Soils classifications of disaggregated samples of Brule Formation were sandy silt and silty sand with some plasticity. The lab classifications differ from a visual classification of a sample of the Brule Formation that was dried for several weeks, wetted, and

manually disaggregated. The visual classification was clayey silt with sand. Visually, the sample had approximately 20 percent fine to medium subangular sand, and 80 percent fines with medium dry strength, slow dilatancy, and medium toughness. The differences in the classification could be due to variation in the Brule Formation, or insufficient breakdown of the laboratory sample. The uniaxial compressive strengths ranged from 547 to 1,056 lb/in^2, with an average value of 836 lb/in^2. Apparent cohesions varied from zero to 11 lb/in^2 maximum, with a average value around 6 lb/in^2. Friction angles varied from 24 to 42 degrees, with an average of 33 degrees.

e. Dikes Drill Holes: Drill holes DH07-2, -3, and -4 were drilled from the crest of Dike 1 (Sta. 6+90), Dike 2 (Sta. 15+25), and Dike 3 (Sta. 40+75) respectively and were drilled to depths of 75.0, 85.0, and 75.0 feet respectively. Each of the dike drill holes encountered 0.6 inches of asphalt surfacing. Beneath the asphalt surfacing, dam embankment was encountered to a depth of 32.5 feet in DH07-2 (Dike 1), 41.5 feet in DH07-3 (Dike 2), and 27.3 feet in DH07-4 (Dike 3). In DH07-2 (Dike 1), the embankment was visually classified as sandy lean clay with a maximum size of 3-inches. Below a depth of about 20 feet, the embankment was laboratory classified as lean clay, lean clay with sand, silt, and silt with sand. In DH07-3 (Dike 2), the embankment was visually classified as sandy lean clay with gravel with a maximum size of 2-inches from 0.6 to 1.3 feet, and sandy lean clay from 1.3 to 41.5 feet. A laboratory sample from 15.0 to 15.3 feet of the embankment was classified as lean clay. In DH07-4 (Dike 3), dam embankment was variably visually classified as sandy lean clay with gravel with a maximum size of 2-inches, sandy lean clay, and sandy silty clay. Laboratory samples of the Dike 3 embankment were silty clayey sand with gravel, silty clayey gravel with sand, sandy silty clay, and lean clay. Brule Formation (Tb) was encountered beneath the embankment in each dike drill hole.

3. Test trench TT07-1 and test pits TP07-1 and TP07-2 were excavated using a John Deere 200LC excavator. TT07-1 and TP07-2 are located upstream of Dike 3. TP07-1 is located upstream of Dike 1. These excavations were completed to try to locate potential paths of seepage in the Brule Formation, such as open joints and/or bedding planes, or pervious lenses or beds that could cause seepage to increase significantly when reservoir water surface reaches elevation 4625. No obvious open joints or pervious zones were encountered.

a. TT07-1 was excavated on the south side of the old railroad upstream of Dike 3. Due to limited area so that Glendo Park facilities were not impacted, the trench was a side-hill cut into the slope. The depth from the top to the bottom of the slope was about 26.1 feet. The dimensions of the trench were approximately 90 feet long by 50 feet wide (from top to bottom of slope) by 26.1 feet deep. Materials encountered were loess and Tb. Loess was approximately 12 feet thick and consisted of no to low plasticity silt. The upper 4.7 feet of Tb, from 12.0 to 16.7 feet deep was intensely weathered and very intensely fractured.

b. TP07-1 was excavated to a depth of 24.0 feet in silt interpreted to be part of the buried channel that is present beneath Dike 1. This test pit did not encounter bedrock.

c. TP07-2 was excavated on the north side of the old railroad cut. Tb was encountered at the surface and consisted of moderately weathered and slightly fractured siltstone with thin to thick patches and fracture fillings composed of green high plasticity clay.

4. There have been concerns about the potential for erosion of the Brule Formation below the auxiliary spillway in previous studies primarily due to its weathering characteristic when the Brule loses its in situ moisture. Based on observations, field explorations, and material property testing, the Brule Formation is recognized to exhibit both rock-like and soil-like characteristics. Remolded samples contain some clay, and the in situ material has resistance to detachment of soil particles that seems similar to that of stiff clay materials. JET erosion tests were performed in the test trench and confirmed that the Brule Formation in its unweathered insitu condition behaves more like a rock than a soil.

5. The most recent field investigations for Final Designs include three test pits near the right (west) abutment of Dike 1 to determine the extent of loess that comprises the buried channel. DH09-D1-1, -2, and -3 were excavated to depths of 9.0, 20.0 and 16.0 feet respectively. Brule Formation (Tb) bedrock was encountered in DH 09-D1-1 at a depth of 1.3 feet overlying fill. The upper approximately three feet of Tb was intensely to moderately fractured. Below this depth, Tb was moderately fractured. DH09-D1-2 was excavated closer to the dike in fill from 0 to 2.5 feet and loess (Ql) from 2.5 to 20.0 feet. Loess was laboratory classified as lean clay with a liquid limit of 29 and PI of 9. DH09-D1-3 was excavated in fill from 0 to 1.5 feet, loess (Ql) from 1.5 to 14.0 feet, and Brule formation (Tb) from 14 to 16.0 feet. Strongly cemented loess (caliche) was encountered from 9.0 to 14.0 feet.

1.04 REGIONAL GEOLOGY

A. Glendo Dam is located in a synclinal basin formed by the Hartville Uplift to the southeast and the Laramie Mountains to the northwest. The oldest rocks in the area are Precambrian crystalline rocks exposed by the Hartville Uplift. The oldest sedimentary rocks in the area are Mesozoic rocks with a regional dip of to the southeast roughly five degrees or less on the west limb of the syncline. The Jurassic rocks are overlain by nearly horizontally bedded younger Tertiary sedimentary rocks.

B. The area is characterized by high rolling plains, dissected by rivers and streams exposing older sedimentary rock. The Mesozoic sedimentary rocks support trees and grasses whereas the younger Tertiary sedimentary rocks are generally barren of trees and support only shrubs and grasses.

C. Seismicity in the Glendo area has historically been low and the seismic hazard is also considered to be low. No major faults or shears are known to be present at the site. Historic seismicity in the area generally sparse and faults with documented Quaternary activity are not known to be present in the region. The most recent seismic hazard studies, completed in 2001 indicate the Peak Horizontal Acceleration (PHA) values for the 10,000 and 50,000 year events are .19 and .34 g respectively.

1.05 SITE GEOLOGY

A. In the immediate area of the dam, the North Platte River has cut a canyon 300 feet deep through the Cloverly (Dakota) and Morrison Formations into the upper part of the Sundance Formation. Successively older sedimentary rocks crop out upstream. These older formations are overlain unconformably throughout most of the area by Tertiary sediments.

B. The reservoir basin is an erosional valley in gently dipping sedimentary rocks. The age of the formations ranges from Permian in the upper reaches of the basin to the younger Cretaceous beds at the damsite. In the reservoir area west of the damsite, the older sedimentary rocks are overlain unconformably by extensive Tertiary deposits consisting of horizontally bedded tuffaceous and bentonitic claystone and siltstone. In places, flat-topped knolls of the Tertiary deposits have been left as erosional remnants and are capped with a thin veneer of coarse-grained terrace alluvium. Water tests in drill holes along the railroad relocation indicate that the Tertiary sediments are relatively impervious; recent drill holes indicate secondary permeability due to local open discontinuities in the rock mass. The stream alluvium from the active channel of the North Platte River and its tributaries is composed of sand, gravel, cobbles, and boulders with some clay. Alluvial terraces composed of sand, silt, and a small amount of clay also occur in the reservoir basin near river level. Loess (wind blown deposits) covers much of the area west of the damsite from a thin veneer to up to about 60 feet in the buried channel beneath dike 1.

C. Both man-made and natural materials will be encountered in the work. Man-made materials include dam and dikes embankment Zones 1 and 2, riprap that was placed on the upstream face of the dam and dikes, and miscellaneous fill (Fill). Surficial geologic units include talus and three Quaternary units: colluvium (Qc), loess (Ql), and terrace alluvium (Qta). Bedrock includes the Tertiary Brule Formation (Tb) at the auxiliary spillway and dikes; and the Cretaceous Cloverly (Dakota) Formation (Kc) and the Jurassic Morrison Formation (Jm) at the dam abutments.

1. <u>Zone 1 dam embankment.</u> The Zone 1 dam embankment core is constructed of selected clay, silt, sand, and gravel from onsite borrow sources in the reservoir compacted by tamping rollers to 6-inch layers. Compaction of the zone 1 material

was generally good with an average fill dry density of 109.0 pounds per cubic foot for the minus No. 4 material which was 100.9 percent of the comparable laboratory compaction tests of 108.0 pounds per cubic foot. Samples of zone 1 recovered from drill hole PR87-3 at the downstream edge of the dam crest were laboratory classified as mostly brown sandy lean clay (CL) and silty clay (CL-ML) with minor intervals of lean clay (CL), clayey silt (ML-CL), and sandy silt (ML). The sand was mostly fine sand. Fines content varied from about 51 to 86 percent, averaging about 68 percent. Up to about 10 percent fine, hard, subangular to subrounded gravel was present in the zone 1 samples. Liquid limits ranged from 24 to 33 and plasticity indexes (PI) ranged from 5 to 17. Two samples were nonplastic (NP). Standard Penetration Test (SPT) blow counts in the Zone 1 dam embankment ranged from 50 blows per 0.8 feet to 50 blows per 0.4 feet.

2. Zone 1 dikes embankment. The Zone 1 dikes embankment core is constructed of material from the same source as that of the dam zone 1. Field densities of the dikes zone 1 material averaged 107.1 pounds per cubic foot which was 99.6 percent of the standard laboratory maximum dry density of 107.5 pounds per cubic foot. Samples of zone 1 recovered from DH07-2, and DH07-3, drilled in Dikes 1, and -2 respectively were laboratory classified as lean clay (CL) and silt (ML) with up to 23 percent sand. Samples of zone 1 recovered from DH07-4 drilled into Dike 3 ranged from lean clay (CL) to silty clayey gravel with sand (GC-GM). Up to 49 percent hard, subrounded to subangular gravel to 2-inches in diameter was present in the zone 1 samples at Dike 3.

3. Zone 2. The Zone 2 embankment consists of selected sand, gravel, and cobbles compacted by crawler-type tractors to 12-inch layers. Zone 2 was obtained from onsite borrow areas. The zone 2 was variable and included clean well-graded sand, clean well-graded gravelly sand, silty sand, silty gravel, and clean well-graded gravel. The minus No.200 material varied from one to 28 percent, averaging 10 percent. The percent passing the No. 4 sieve varied from 42 to 91 percent, averaging 57 percent. The plus 3-inch rock varied from zero to 25.8 percent, averaging 6 percent. SPT blow counts in the zone 2 from drill holes PR88-2 and PR87-3 ranged from 12 blows per foot to 50 blows per 0.4 feet.

4. Riprap. Existing riprap consists of a shaly limestone that has deteriorated since the original construction of the dam. Existing sizes range from about three to four feet in diameter to chips of rock. The riprap was obtained from a limestone quarry located about four miles east of the dam that was depleted. Riprap was placed on the upstream face of the dam above elevation 4545. Riprap was placed on the entire upstream face of each dike. Riprap will be encountered in the excavations for the dam and dikes raise and Glendo Park Road relocation. Along the Glendo Park Road relocation, riprap consisting of hard cobbles and boulders, up to about four feet in diameter, exists. Existing riprap is present along the drainages downstream of the weir boxes for the seepage berms.

5. Fill. Fill consists primarily of road fill placed along the dam access roadway and was variably classified as silty clay with sand and cobbles (ML-CL)sg and clayey sand with gravel (CL)g. Fill was encountered in recent test pits near the right abutment of Dike 1 as encountered in drill holes. Fill will be encountered along the dam access roadway at the dikes and auxiliary spillway. Existing roadway at dikes consists of 0.6 feet of asphalt as encountered in drill holes and plus or minus 0.8 feet of roadbase material. Fill consisting of railroad ballast is present along the Glendo Park Road relocation downstream of Dike 3 in the old railroad grade.

6. Talus. Talus consists of unconsolidated fines to boulder-size rock blocks that have accumulated at the base of the steep right abutment slope of the dam. Maximum size boulder exposed at the surface is about six by six by at least two feet thick. The thickness of talus is not known, but, soft bedrock is exposed about 20 feet back from and about 18 feet above the toe of the slope. The steep right abutment slope was scraped off to bedrock for the original placement of the dam embankment.

7. Quaternary Colluvium (Qc). Where present, colluvium is generally up to about three feet thick and composed of a variable mixture of silt, lean clay, sand, gravel, cobbles, and a few small boulders eroded from local terrace deposits, loess, and the underlying bedrock. Along the reservoir rim, colluvium or terrace alluvium up to about 20 feet was encountered in drill holes. Some of this material was removed during the construction of the dam access road

8. Quaternary Loess (Ql). Loess consists mostly of silty or clayey fines and fine sand deposited by wind. Extensive deposits of loess are present at the site overlying the Brule Formation and terrace alluvium. Loess is up to about 60 feet thick at Dike 1 where it comprises the fill of the buried channel. The buried loess filled channel materials are essentially impermeable and would not take grout during the early 1970’s grouting program. Loess may contain traces of gravel and local boulders, particularly in borrow areas.

    a. Caliche (Ql(cal)). Consists of zones of strongly carbonate cemented loess encountered in Borrow Area 4. Ql(cal) as encountered in test pits ranges from 1.0 to 17 feet thick.

9. Quaternary Terrace Alluvium (Qta). Terrace alluvium consists of unconsolidated generally coarse-grained alluvium, but includes silty and clayey sand to well graded gravel with sand, cobbles, and boulders. Terrace alluvium varies from a few feet thick up to about 40 feet thick overlying the Brule Formation in the borrow areas. Terrace alluvium is present on the ridge above Dike 3 where it is up to at least 14 feet thick.

10. Tertiary Brule Formation (Tb). The Brule Formation is comprised of soft to moderately soft, compact to weakly cemented siltstone and claystone beds. The Brule Formation is part of the White River Group of rocks which are known weak rocks and which at this site are poorly consolidated and poorly cemented which results in low strengths. The Brule Formation (Tb) can be indented with knife

point to 1/4-inch and can be scratched with a fingernail; locally it is poorly indurated. Lab test data indicate the Brule Formation (Tb) has compressive strengths ranging from 547 to 1056 pounds per square inch (psi). The Brule Formation (Tb) air slakes and breaks up moderately to rapidly into mostly flakes and plates after it is air dried and then saturated. The Brule Formation (Tb) is intensely to moderately fractured to depths ranging from two to about 20 feet. Below depths from about two to 20 feet, the rock is slightly fractured to massive. The Brule Formation forms the narrow ridge along the south side of the reservoir and will be encountered excavations for the Auxiliary Spillway and at the dikes abutments.

11. Cretaceous Cloverly (Dakota) Formation (Kc). The Cloverly Formation (Kc), also known as the Dakota Formation is predominantly fine- to medium-grained sandstone interbedded with some irregular shale lenses. The sandstone is hard and much more resistant than most of the rock in the area and forms the caprock on the abutments of the dam. Although the sandstone is more resistant than the Morrison Formation (Jm), it was found to be of poor quality for riprap because it is moderately friable, very porous, absorptive, and tends to soften when immersed in water.

12. Jurassic Morrison Formation (Jm) underlies the Cloverly Formation and makes up the lower slopes of the canyon walls along the North Platte River. The greater part of this formation consists of interbedded shales and sandstones containing varying amounts of calcium carbonate and thin lenticular limestones. The calcium carbonate-rich portions of the rock are competent, but the shales containing little calcium carbonate air slake rapidly and required special treatment during construction. The formation is variegated in color, with green, gray, and purple predominating. Most of the dam abutments are founded on the Morrison Formation (Jm). Erosion of the Morrison Formation (Jm) on the left abutment has resulted in local sliding in the softer shales and undercutting of the overlying Cloverly Formation (Kc) resulting in toppling of sandstone blocks. Fine-grained units in Jm are prone to deterioration. Portions of the outlet works tunnel are founded in the Morrison Formation (Jm) where the shale beds were sprayed with bituminous coating immediately after excavation to prevent detrimental slaking.

1.06 WATER OCCURANCE

A. The sources of water that could enter excavations during construction are surface water and groundwater. Surface water from rainfall and snowmelt could enter all of the excavated areas. At the auxiliary spillway site groundwater from the reservoir and from perched water due to infiltration of precipitation could also be present. Seepage of reservoir water downstream of the dikes could impact the excavations for the dam access road relocation and construction activities downstream of the dikes. Seepage has historically been observed downstream of all three dikes. Wet areas have been reported near PTP-3 downstream of Dike 1 when the reservoir is above about elevation 4630. Wet areas have also been reported in low areas downstream of all three dikes. Reservoir water on the upstream side of the dikes could impact construction activities on the upstream side of the dikes. Historically, reservoir water rarely encroaches upon the upstream face of Dikes 1 and 2, but, routinely loads Dike 3 in the low area of the abandoned railroad grade. Surface runoff from the dikes seepage berm weir boxes may impact Glendo Park Road relocation. Seepage at the dikes and auxiliary spillway is described in more detail under Groundwater and Seepage article.

1.07 GROUNDWATER AND SEEPAGE

A. Although water tests in drill holes along the railroad relocation and the south reservoir rim indicate the Brule Formation (Tb) is relatively impervious, vertical joints and horizontal bedding planes in the Brule form secondary permeability. Seepage has historically been observed downstream of all three dikes. Seepage was significant enough that a grouting program was completed in the early 1970's at the dike abutments. Seepage continued after the grouting program and seepage berms and drainage collection systems were installed in the 1980's downstream of the dikes. Seepage downstream of the dikes significantly increases at reservoir elevations that range from 4620 to 4625. Excavations below about elevation 4651 may encounter groundwater from a perched water level in the Brule Formation (Tb). Depending on the reservoir elevation at the time of excavation, seepage from the reservoir may be encountered. Seepage flows into the excavations are expected to be up to a maximum of 175 gpm. Water is expected to be controllable through sumps and pumps. Small trenches or drainage ditches on the downstream side of the excavation may facilitate unwatering. It is thought that seepage occurs through a circuitous path of open joints and bedding planes in the Brule Formation (Tb). Piezometers installed at the Auxiliary Spillway site indicate the presence of perched water although the volume is considered small in addition to potential reservoir seepage.

B. Water Levels and Water Occurrences

1. Auxiliary Spillway

a. Data sources are shown on Geologic Drawings 449-D-1644 through -1647. Data Sources include the following:

1) Drill holes DH07-1 (angled) and DH07-5 (vertical), completed as porous tube piezometers PTP07-1 and PTP07-2 respectively. Water level data from PTP07-1 and PTP07-2 since May, 2007 as well as downhole permeability testing.

2) Reports of seepage from open test trench, TT-06-1 and downstream of the auxiliary spillway site.

3) Preconstruction drill holes DH10, DH9E, and DH9W and test pit TP7. Downhole permeability testing and open test pit test for seepage potential.

b. For water hydrographs refer to Appendix A.

c. On August 13, 2009, PTP07-2 was bailed three times. Based on the recovery rates, the water source is not large because the hole did not fill up immediately to pre bailed levels and was lower than the previous bail following each bailing.

d. During the examination for the 2008 Periodic Facility Review on June 17, 2008, it was observed that the ground surface was wet and water flowing between one to five gallons per minute (gpm) downstream of the auxiliary spillway location at about elevation 4690. The reservoir surface at that time was elevation 4638.15.

e. During the annual inspection on May 21, 2009, seepage was observed exiting along a bedding plane in TT-06-1 at about elevation 4650. The reservoir surface at that time was elevation 4630.25, suggesting that the seepage was coming from perched water in the reservoir ridge.

1.08 ENGINEERING GEOLOGY AND GEOTECHNICAL CONSIDERATIONS

A. Geologic units that will be encountered in the excavations include the Morrison Formation (Jm) at both dam abutments; talus at the right abutment of the dam; Brule Formation (Tb) and colluvium (Qc) at the Auxiliary Spillway; and Brule Formation (Tb), possible terrace alluvium (Qta), colluvium (Qc), and loess (Ql) at the dikes and relocated road alignment. Manmade fill consisting of dam embankment zone 1, zone 2, and riprap will be encountered for the dam and dikes raises. Some miscellaneous fill will be encountered locally consisting mostly of roadfill. Common excavation for all excavations for the Glendo Dam Modifications is expected.

B. Excavations in unconsolidated loess and fill were smooth and easy using a CAT 315D excavator. Excavations in well cemented loess and bedrock were slow and difficult using a CAT315D. TP09-D1-1 met refusal in moderately hard and moderately fractured Brule at 9.0 feet using a CAT 315D. Excavations in loess with a John Deere 200LC excavator were smooth and easy. Excavations in Brule Formation bedrock were slow and choppy with a John Deere 200LC excavator.

1. Auxiliary Spillway. The Locations of Explorations and Geologic Sections of the Auxiliary Spillway are shown on Drawings 449-D-1644 through -1647. The Location and Logs of Exploration and Geology of the south reservoir ridge are shown on Informational Drawings 449-D-13 and 449-703-114.

a. <u>Brule Formation (Tb).</u> A 1970 CAT D7F dozer with one ripper tooth was able to excavate to and into fresh Brule Formation in test trench TT-06-1. Excavation in the Brule Formation in the 1950’s for the railroad relocation during the original construction of the dam described the siltstone as quite hard, although the contractor successfully excavated the material without blasting. The contractor used three ripper teeth mounted on a 265-Hp crawler tractor. Each tooth was controlled individually. Siltstone was ripped to a depth of two feet with one pass. There was some difficulty ripping. Part of the time only one tooth could be used and a 191-Hp tractor had to aid by pulling. The Brule Formation (Tb) may be massive at depth. The Brule (Tb) is a weak rock that develops incipient fractures once exposed which may facilitate excavation.

1) Excavated and local natural slopes in the Brule Formation are steep and have experienced raveling and slaking. The 2:1 permanent design slopes should be sufficient.

2) The Brule Formation slakes and breaks down with equipment travel. During excavation for the railroad relocation, the Brule ripped out in hard clods but weathered rapidly and, under traffic, broke down into very fine-grained material. Equipment travel could exacerbate deterioration of the Brule Formation.

3) Because the Brule Formation slakes significantly on exposure and breaks down to fine grained material, it is not suitable for construction material.

4) The Brule Formation rapidly air slakes. As the Brule Formation was exposed during excavation of TT-06-1 it developed hairline and slightly open fractures within minutes; after about one week of exposure, slaking had occurred in the upper approximately 1/2-inch of the surface and numerous hairline fractures had developed as well as separation along fractures. Any defects in the foundation resulting from exposure to air or water may require additional foundation preparation including but not limited to overexcavation.

5) Excavation of the Brule Formation will likely result in blocks 1-foot in size or smaller and the excavated surface is expected to be blocky.

b. Colluvium/Terrace alluvium. Terrace alluvium from 0 up to about 20 feet was encountered in drill holes near the top of the south reservoir ridge. Based on recent drill holes at the auxiliary spillway location, it appears that most if not all of the unconsolidated materials were removed prior to construction of the roadway, at least in the vicinity of the auxiliary spillway. Colluvium is very thin on the side slopes of the ridge and is expected to be less than two feet thick. At TT-06-1, colluvium was one foot thick. Where the slope flattens out on the upstream side of the ridge, colluvium may be thicker, possibly up to about 10 feet thick. Slopes in colluvium/terrace alluvium should be stable at about 2:1.

c. Unwatering. For unwatering see Groundwater and Seepage article.

2. Dike Raise. Locations of Explorations, Bedrock Contours, and Geologic Section E-E’ at the right abutment of dike 1 are shown on Drawing 449-D-1648. Locations of Explorations are shown on Informational Drawings 449-600-223

through -229. Geologic Sections of grout holes of the early 1970's foundation grouting program at the dikes are shown on Informational Drawings 449-732-1, -2, and -3.

a. Brule Formation bedrock will be encountered at the dike 1 right abutment tie-in, possibly at the left abutment of dike 3, and possibly between dikes 2 and 3 near station 19+00. The upper three to five feet of the Brule Formation may be intensely fractured and intensely weathered and unsuitable for foundation.

b. At the right abutment of Dike 1 loess (Ql) that fills the buried channel will form the foundation for the dike raise. Loess is generally soft and may be sensitive to changes in moisture. Equipment travel on loess should be kept to a minimum. Special foundation preparation of loess may be required.

c. Colluvium may be encountered at the left abutment of dike 3. Colluvium is composed of a variable mixture of silt, clay, sand, gravel, cobbles, and boulders and will likely require removal to suitable bedrock. It is anticipated that colluvium will be up to about three feet thick overlying bedrock.

d. Fill as described in Site Geology article will be encountered.

3. Dam Raise.

a. At the tie-in to the dam abutments, the excavations will be in soft sedimentary rocks of the Morrison Formation (Jm) which will form the foundation for the 3- foot dam raise. The existing abutment slopes are 1:1 and were excavated during the original construction of the dam using a crawler tractor to push overburden down the slope. On the left abutment, a tractor equipped with a winch line was used to assist with this process because of the 1:1 slopes.

1) On the left abutment, the Morrison Formation (Jm) consists of alternating beds of shale, sandstone, and conglomerate generally less than one foot thick. Sliding of the Morrison Formation materials on the left abutment slope has resulted in repeated slope stabilization efforts over the approximate 60 year history of the dam. Sliding and sloughing of the Morrison Formation (Jm) beds on the left abutment has undermined the resistant overlying Cloverly Formation (Kc) resulting in toppling of hard blocks onto the steep left abutment slope. The left abutment geology is shown on design drawing 449-D-1612.

2) On the right abutment of the dam, talus is present overlying the Morrison Formation (Jm). As exposed at the surface, local large blocks six feet by six feet by two feet or more are present. Talus will require removal to suitable bedrock foundation at the foundation tie-in for the 3-foot dam raise. The presence of large

blocks may require special handling for removal. The right abutment geology is shown on design drawing 449-D-1612.

4. Glendo Park Road Relocation.

a. Cuts up to about 28 feet are anticipated in Brule Formation (Tb) and overlying colluvium and/or Terrace Alluvium. Slopes should be stable at 2:1. The Brule Formation (Tb) will require ripping below a depth of three to four feet where it is moderately fractured to massive. The upper approximately three to four feet of Brule in the vicinity of the dikes is intensely fractured and can be excavated with backhoe or excavator.

b. Excavations for the road relocation may encounter waste material that was disposed of a minimum of 100 feet downstream of the toe of the seepage berm embankments (Reference i). The waste material was placed so as not to have a detrimental effect on the toe drain system or natural drainage.

C. Drilling.

1. Drilling for rock anchors on the left abutment in the Morrison formation (Jm) may be difficult because much of the Morrison (Jm) is soft and susceptible to slaking. On the left abutment the Morrison Formation (Jm) is also thinly to moderately bedded with maximum thickness of about one foot. Near-horizontal to dipping five degrees southeast (out of the slope and toward the right abutment), bedding breaks may be present which could result in loosening of the material and cause jamming of the drill.

1.09 BORROW INVESTIGATIONS

A. Geologic investigations conducted near the Glendo dikes for borrow materials that are relevant to these specifications were completed in 1986 for the Seepage Berm Modifications to the dikes. Test pits were excavated during the Seepage Berm Construction to determine locations of additional borrow materials and to determine the depth of stripping. Borrow investigations for this specification were completed in 2008 and 2009 and Borrow Areas 3 and 4 were selected as preferred borrow areas. These borrow investigations are listed below; and available logs of investigations are contained in Section 53 20 00 - Records of Geologic and Subsurface Investigations.

B. Previous Investigations.

1. The borrow investigations for the Dikes Seepage Berm Modifications included portions of Borrow Area 4 for these specifications. Twenty two test pits, TP86-1 through -22 were excavated in an area northwest of the dikes. The area is shown on informational drawing 449-D-1577. The area investigated, locations of test pits, surficial geology, and locations of geologic sections developed at the time are shown on informational drawings 449-D-1578 and -1579. Explorations in the borrow area indicated that the materials are variable in nature and texture and

contain variable amounts of moisture and plus 5-inch material. Geologic sections developed in the seepage berms borrow area are included in information drawings 449-D-1580 through -1583. Details of the 1986 borrow investigation are in Reference 14.

2. During construction of the Seepage Berms, seven additional test pits were excavated in the borrow area to determine locations of suitable sand and gravel borrow materials for the gravel envelope. The contractor was having difficulty locating sufficient sand and gravel filter material which required a gradation of nine percent or less No. 200 and a maximum size of 3-inches. In addition, several test pits were excavated to determine the thickness of unsuitable, fine-grained materials that would require removal before accessing the underlying sand and gravel materials. Details of the seepage berm construction are in Reference 9.

C. Current Investigations. Onsite borrow investigations included a preliminary investigation to determine the feasibility of using onsite materials and a final design borrow investigation. The borrow investigation for final design was completed to further define potential onsite materials and quantities. Four areas were investigated near the Glendo dikes. Based on laboratory test data, anticipated quantities of available materials, and locations well above any influence from the reservoir, Borrow Area 3 and Borrow Area 4 were selected as the preferred borrow areas as sources for zone 1A and zone 3A embankment, soil cement aggregate, and miscellaneous roadfill. Results of laboratory test data indicate that sufficient quantities of low permeability materials for zone 1A embankment can be obtained from mostly fine-grained material from borrow. The Zone 3A embankment shell and soil cement aggregate can be obtained from coarse-grained materials from borrow. Roadfill may be obtained from both coarse grained and fine grained materials.

1. A preliminary borrow investigation was conducted to determine the potential of using onsite materials. Thirty eight test pits, were excavated in areas around the reservoir. Of these, four test pits in Borrow Area 3, TP08-1WR through -4WR; and five test pits in Borrow Area 4, TP08-1OBP through -5OBP are relevant to these specifications. Laboratory tests included gradations and Atterberg Limits. Results of the preliminary borrow investigation indicated it was feasible to obtain onsite borrow materials for zone 1A and zone 3A embankment, soil cement aggregate, and miscellaneous roadfill. Summary physical properties test results for materials sampled during the preliminary borrow investigation and geologic logs of test pits are included in these specifications. The locations of test pits adjacent to the dikes are shown on drawing 449-600-583.

2. A borrow investigation for final design was completed to further define potential onsite materials and quantities. The borrow investigation for final design included 71 test pits, TP09-B1-1 through -B1-10, -B2-1 through -B2-39, -B3-1 through B3-7, and -B4-1 through B4-18. Laboratory tests of materials for the final design borrow investigation included gradations, Atterberg Limits, inplace densities, Proctor Compaction tests, and crumb tests on selected materials with a PI greater than about 13. Potential sources for soil cement aggregate were used in

mix designs for soil cement. The locations of the final design borrow investigation test pits, preliminary borrow investigation test pits in areas further explored, the preferred borrow areas, and locations of geologic sections are shown on Drawing 449-600-583. Geologic Sections that illustrate the extent and distribution of materials are shown on Drawings 449-600-585 through -589. Summary physical properties test results for materials sampled during the final design borrow investigation and test pit logs for Borrow Areas 3 and 4 are included in these specifications. Results of the investigations in Borrow Area 3 and Borrow Area 4 are discussed below in Borrow Areas – Materials article.

D. Borrow Areas - Materials. The generalized stratigraphy of both preferred borrow areas is similar: Unconsolidated predominantly coarse-grained Quaternary terrace alluvium overlain locally by predominantly fine-grained loess. These unconsolidated materials were deposited on an irregular bedrock surface comprised of the Brule Formation (Tb).

1. Borrow Area 3 is located about 3200 feet north of the dikes on top of a peninsula trending northwest-southeast that juts out into the reservoir for about 4000 feet. The borrow area is irregularly shaped and is shown on Drawing 449-600-583. As shown on Area 3 Geologic Section A-A' (drawing 449-600-585), borrow area 3 is comprised primarily of coarse grained sediments.

   a. The coarse grained sediments as encountered in test pits range from about 6 feet to at least 18 feet thick. Laboratory classifications of coarse grained materials in Borrow Area 3 range from clayey sand with gravel (SC) with up to 10 percent cobbles, to well graded gravel (SW), to well graded gravel (SW) with up to 35 percent cobbles and trace boulders, to well graded sand with silt and gravel (SW-SM) with up to 15 percent cobbles and trace boulders. Excavations were difficult using a Caterpillar 315D excavator where cobbles and boulders were encountered.

   b. Fine grained materials encountered in Borrow Area 3 ranged from about one foot to up to eight feet thick and were only encountered in three test pits. Laboratory classifications of fine grained materials in borrow Area 3 ranged from lean clay to clayey silt to silt. One sample of fine-grained material classified as lean clay (CL) had a LL of 35 and PI of 24.

2. Borrow Area 4 is located from about 600 to about 4800 feet northwest of the right abutment of dike 1. The ground surface of Borrow Area 4 is very irregular and heavily dissected with local short, narrow ridges and knolls with intervening drainages. The southern approximately one third of the borrow area was a designated borrow area for the seepage berm modification to the dikes where coarse-grained materials were required. Based on a comparison of recent topography and used for the Seepage Berms Borrow drawings, the topography that was some of the surface of borrow area 4 appears to have been modified since the 1980’s due to disturbance of this area for obtaining materials to construct the seepage berms. Based on Reference i, additional borrow materials for the Seepage Berm modification were obtained further north from the

originally designated borrow area and from state land because insufficient coarse grained material was available in the designated borrow area. Areas within Borrow Area 4 other than the designated Seepage Berm Borrow Area may also have been disturbed from prior use as a borrow area.

a. Brule Formation (Tb) bedrock was encountered in 11 of the 23 test pits in Borrow Area 4, at depths ranging from 2.5 to 18.5 feet (elevations ranging from about 4701 in TP09-B4-16 to 4730 in TP09-B4-15). Several test pits, TP09-B4-4, -6, -8, -11, -15, and -18 encountered caliche (Ql(cal)).

b. Coarse grained material in Borrow Area 4 as encountered in test pits ranged from 1.5 (TP09-B4-16) to 16.5 (TP09-B4-9) feet thick, mostly 5 to 13 feet thick. As exposed in test pits, coarse grained materials are locally overlain by up to about 10 feet of fine grained materials. Laboratory classifications of coarse grained materials include well graded gravel with silt and sand (GW-GM); poorly graded gravel with silt and sand (GP-GM) with up to 10 percent 3- to 5-inch cobbles; silty, clayey sand with gravel (SC-SM) with up to 10 percent plus 3-inch material; clayey sand (SC); silty sand with gravel (SM) with up to 5 percent 3- to 5-inch cobbles and trace 5- to 12-inch cobbles and boulders; poorly graded sand with silt (SP-SM) with 25 percent 3- to 5-inch and trace 5- to 12-inch cobbles; clayey sand with gravel (SC); clayey gravel with sand (GC) with trace cobbles and boulders; and well graded gravel with silty clay and sand (GW-GC) with up to 15 percent cobbles and trace boulders. Up to 25 percent cobbles, and boulders are present with a maximum size encountered of 2.5 feet in diameter. One inplace density in a well gradel gravel with silt (GW-GM) had a dry unit weight of 125.7 pounds per cubic foot (lbs/ft3) at a moisture content of 4.9 percent. The laboratory compaction test had a maximum dry unit weight of 129.4 lbf/ft3 at optimum moisture of 9.2 percent.

c. Fine-grained materials encountered in test pits in Borrow Area 4, ranged from 2.3 to 19 feet thick. The fine grained materials were laboratory classified as lean clay (CL), clayey silt (CL-ML), clayey silt with sand (CL-ML)s, and lean clay with sand (CL)s. These materials have a minus 200 content ranging from about 81 to 92 percent, with liquid limits (LL) ranging from 27 to 36 (average about 30), and plasticity indexes (PI) ranging from 5 to 19 (average about 10). One inplace density test in the lean clay had a dry unit weight of 89.1 pounds per cubic foot (lbs/ft3) at moisture content of 12.0 percent. The laboratory compaction test on this sample had a maximum dry unit weight of 107.5 lbf/ft3 at optimum moisture of 17.8 percent. Crumb tests were performed on fine grained materials with PI's ranging from 8 to 15. All samples classified as nondispersive, except for one from TP09-B4-1 from 0.0 to 14.4 feet, which classified as Intermediate.

E. Borrow Materials Geotechnical Considerations.

1. Borrow Areas 3 and 4 are the preferred borrow areas. It is anticipated that all of the Zone 1A and Zone 3A embankment, soil cement aggregate, and miscellaneous roadfill can be obtained from onsite Borrow Areas 3 and 4.

2. The geologic depiction of estimated soil stratigraphy is based on limited data and represents the interpretation used for design. The geologic drawings portray generalized geologic conditions. The geologic logs of explorations and laboratory test data should be consulted for specific details. Wide variation in the nature, texture, moisture content, cementation, percentage of oversize, and continuity of materials as indicated by the explorations is to be anticipated in both borrow areas. Borrow area materials are variable and can change both laterally and vertically in short distances. The Contractor is encouraged to complete its own investigations to determine locations within the preferred borrow areas where suitable material that meet the requirements of this specification can be found.

3. Borrow Areas 3 and 4 are located well above the reservoir and none of the test pits in these two areas encountered water during excavation. It is anticipated that the only source of water in the borrow areas will be runoff from rainfall and possibly local perched water or infiltration from precipitation.

4. Up to about two feet of topsoil containing roots and grasses was encountered in test pits which will need to be removed prior to extracting borrow materials.

5. Borrow Area 4.

    a. Two sub-parallel power lines are present in Borrow Area 4. The locations of the power lines are shown on drawing 449-600-583. The power lines trend northwest-southeast crossing through the central portion of the borrow area and are approximately 400 feet apart. Caution near the overhead power lines and care near the towers to avoid undermining the foundations will be required. These requirements are outlined under Section 01 56 15 – Protection of Existing Utilities and Section 31 23 18 – Excavation from Borrow.

    b. In general, borrow materials are segregated into mostly fine-grained and mostly coarse-grained areas that form an irregular patchwork as exposed at the surface. Locally, coarse grained materials are overlain by up to at least 10 feet of fine grained materials. The distribution of various types of materials is irregular and may require further investigations to determine the most favorable areas for extraction.

    c. Portions of Borrow Area 4 were used for the Seepage Berms borrow and some of the remaining material may be reworked, waste material, or otherwise disturbed. The Seepage Berm final construction report, Reference 9 indicates that insufficient coarse-grained material was obtained from the original Seepage Berms borrow area located in the southern portion of Borrow Area 4 and that material had to be obtained in an alternate area in the more northern portions of Borrow Area 4 as well as from State Land. Also, stripped material (fine grained materials) was pushed back into the borrow area, and slopes and drainages were shaped and dressed.

d. Brule Formation (Tb) bedrock was encountered in 11 of the 23 test pits in Borrow Area 4, at depths ranging from about 2.5 to 18.5 feet (elevations ranging from about 4701 in TP09-B4-16 to 4730 in TP09-B4-15). The presence of bedrock, particularly shallow bedrock, will influence the thickness of available materials. Details of the depths to bedrock are on the geologic logs and shown on the geologic sections in drawings 449-600-587, -588, and -589.

e. Several test pits, TP09-B4-4, -6, -8, -11, -15, and -18 encountered caliche (Ql(cal)) and should not be used for embankment zone 1A. As encountered in the borrow investigations, these materials were encountered in test pits in the southern half of the borrow area. The depths at which these materials were encountered in test pits ranged from 0 in TP09-B4-18 to 19.5 feet in TP09-B4-11. The geologic logs provide detailed descriptions of these materials and geologic sections on drawings 449-600-587, -588, and -589 shown the distribution of these materials.

f. Zone 1A embankment material. Laboratory test results indicate that impermeable material for zone 1A can be obtained from fine-grained materials. Broad areas of fine grained impermeable materials are present locally in Borrow Area 4. These areas include one near the southwest corner of the borrow area as shown on drawing 449-600-583 and possibly in the northern tip of the borrow area.

g. Zone 3A embankment material. It is anticipated that sufficient quantities of Zone 3A embankment are available in Borrow Area 4 from coarse grained materials. The inplace materials may require processing to remove particles greater than 6-inches in size. Borrow investigations indicate that up to about 15 percent plus 5-inch particles may be present in suitable coarse-grained materials. Possible areas where coarse grained materials can be extracted are outlined on drawing 449-600-583. In addition to the outlined areas, zone 3A materials may be present in the west central portion of the borrow area.

h. Soil Cement Aggregate. It is anticipated that sufficient quantities of soil cement aggregate are available in Borrow Area 4 from coarse grained materials. The inplace materials will likely require processing to remove plus 2-inch sizes. Borrow investigations indicate that up to about 25 percent plus 3-inch particles may be present in suitable coarse-grained materials. Possible areas where coarse grained materials can be extracted are outlined on drawing 449-600-583.

i. Miscellaneous Roadfill. Possible areas of roadfill include coarse grained materials in the southeastern portion of Borrow Area 4, and in the west-central portion of the borrow area. Fine grained materials may be acceptable for roadfill. Large areas of fine-grained material are present in the southwest and north portions of the borrow area.

6. Borrow Area 3.

a. An underground telephone line is located within the borrow area along the north side of the existing road that accesses the end of the peninsula. This phone line will need to be protected. The location of the phone line is shown on drawing 449-600-583.

b. Mostly coarse grained material is present in borrow area 3 which would be suitable for Zone 3A embankment, soil cement aggregate, and miscellaneous roadfill.

c. Local thin lenses up to about two feet thick within the coarse grained materials consist variably of clay, sand, or caliche (Ql(cal)). This may result in selective wasting of unsuitable materials or mixing of materials to meet specified gradations.

d. Fine grained materials up to about 8.5 feet thick were encountered in test pits. These materials may or may not be suitable for zone 1A embankment. Only one sample of CL material was laboratory tested which had a LL of 35 and PI of 24, and would be suitable for zone 1A embankment.

e. Removal of fine grained material may be required locally to reach coarse grained materials in Borrow Area 3.

f. Coarse grained materials in Borrow Area 3 encountered in test pits had up to about 35 percent cobbles, and trace boulders and will likely require processing to remove oversize, particularly for soil cement aggregates.

END OF SECTION

SECTION 53 20 00

RECORDS OF GEOLOGIC AND SUBSUFACE INVESTIGATIONS

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G174.	DH 12+90	
G175.	DH 16+65	
G176.	DH 20+01	
G177.	DH 26+05	

D. Summary of Physical Properties Test Results

1. Auxiliary Spillway and Dikes

G178.		GLENDO DAM – EMBANKMENT SAMPLES
G179.	TP-07-1	Particle Size Distribution Report, 1.1 – 3.1 feet, Sample No. 11J-281
G180.	TP-07-1	Grain Size Distribution Report, 1.1 – 3.1 feet, Sample No. 11J-281
G181.	TT-06-1	Particle Size Distribution Report, Sample No. 11J-221
G182.	TT-06-1	Grain Size Distribution Report, Sample No. 11J-221
G183.	TT-06-1	Particle Size Distribution Report, Sample No. 11J-222
G184.	TT-06-1	Grain Size Distribution Report, Sample No. 11J-222
G185.	Table 1	Soil Physical Properties Test Results, DH-07-5
G186.	Table 2	Uniaxial Compression Strength Test Results, DH-07-5
G187.	Table 3	Direct Shear Test Results

2. Borrow Areas

G188.	Table 1	Summary of Physical Properties Test Results - 2009 Borrow Investigation, Sheet 1 of 3 (includes TP-09-D1-2 and -3 at Dike 1)
G189.	Table 1	Summary of Physical Properties Test Results - 2009 Borrow Investigation, Sheet 2 of 3
G190.	Table 1	Summary of Physical Properties Test Results - 2009 Borrow Investigation, Sheet 3 of 3
G191.	Table 2	Summary of Physical Properties Test Results - 2008 Borrow Investigation, Sheet 1 of 3
G192.	Table 2	Summary of Physical Properties Test Results - 2008 Borrow Investigation, Sheet 2 of 3
G193.	Table 2	Summary of Physical Properties Test Results – 2008 Borrow Investigation, Sheet 3 of 3
G194.	Table 3	Summary of Soil Cement Mix Design Test Results
G195.		Summary of In-place Density Test Results

PART 2 PRODUCTS

Not Used

PART 3 EXECUTION

Not Used

END OF SECTION

7-1336-A (1-86) Bureau of Reclamation	LOG OF TEST PIT	HOLE NO: TP09-B4-18 SHEET 2 OF 2

FEATURE: Glendo Dikes
AREA DESIGNATION: Borrow Area 4
COORDINATES: N744228.6 E710671.6
APPROXIMATE DIMENSIONS: 17.5'x 7.5'x 15.5' deep
DEPTH TO WATER: N/A DATE: N/A

PROJECT: Pick-Sloan Missouri Basin Project
GROUND ELEVATION:
METHOD OF EXPLORATION: 315D Caterpillar Excavator
LOGGED BY: K.Baker
DATE(S) LOGGED: 8/24/2009

CLASSIFICATION GROUP SYMBOL (describe sample taken)	CLASSIFICATION AND DESCRIPTION OF MATERIAL SEE USBR 5000, 5005	% PLUS 3 inch (BY VOLUME)		
		3 – 5 inch	5 – 12 inch	PLUS 12 inch

REMARKS: Site is covered in thick vegetation, weeds, and shrubs with some surface gravels and cobbles.

The test pit was terminated at 15.5 ft after equipment encountered bedrock.

Excavations were smooth and easy from 0.0 to 15.0 ft, when bedrock was encountered.

7-1336-A (1-86) Bureau of Reclamation	LOG OF TEST PIT OR AUGER HOLE	HOLE NO. TP86-1

FEATURE Glendo Dikes Seepage Control
PROJECT Pick-Sloan Missouri Basin Program
AREA DESIGNATION Borrow Area
GROUND ELEVATION 4717.6
COORDINATES N 48,014 E 34,773
METHOD OF EXPLORATION IHC 260 Backhoe
APPROXIMATE DIMENSIONS 3' x 15' x 14.0'
LOGGED BY D. McDonough
DEPTH WATER ENCOUNTERED 1/ Not Encountered DATE 6-17-86
DATE(S) LOGGED 6-17-86

CLASSIFICATION GROUP SYMBOL (describe sample taken)	CLASSIFICATION AND DESCRIPTION OF MATERIAL (Visual-Manual) SEE USBR 5000, 5005	% PLUS 3 in * (BY VOLUME) 3 - 5 in	5 - 12 in	PLUS 12 in
CL/ML	0.0 to 7.0 ft. SILTY CLAY (CL/ML): About 90% fines with low plasticity, low to medium toughness, low to medium dry strength; about 10% predominantly fine sand; maximum size, coarse sand; strong reaction with HCl. In-place conditions: homogeneous, moist, brown. Considerable roots 0 to 1 ft. with scattered roots to 4 ft.			
ML/CL	7.0 to 12.0 ft. CLAYEY SILT (ML/CL): About 90% fines with low plasticity, low toughness, low to medium dry strength; about 10% fine sand; maximum size, coarse sand; strong reaction with HCl. In-place conditions: homogeneous, moist, brown.			
SC	12.0 to 14.0 ft. CLAYEY SAND WITH GRAVEL AND COBBLES (SC): About 65 to 75% fine to coarse, hard, subangular to subrounded sand; about 20% fines with low to medium plasticity, medium toughness, medium dry strength; about 5 to 15% predominantly fine, hard, subangular to subrounded gravel; strong reaction with HCl. Gravel content increases with depth. Original field sample had a trace of hard, subangular to subrounded cobbles, with a maximum dimension of 175 mm. In-place conditions: moist, brown.	T	T	

REMARKS:

Easy to dig with backhoe. Discontinued pit at 14.0 ft. - limit of equipment. Sparse prairie grass cover. Scattered fine gravel on surface.

1/ Report to nearest 0.1 foot

*Estimated

7-1336-A (1-86) Bureau of Reclamation	LOG OF TEST PIT OR AUGER HOLE	HOLE NO. TP86-2

FEATURE Glendo Dikes Seepage Control
PROJECT Pick-Sloan Missouri Basin Program
AREA DESIGNATION Borrow Area
GROUND ELEVATION 4710.1
COORDINATES N 47,780 E 34,701
METHOD OF EXPLORATION IHC 260 Backhoe
APPROXIMATE DIMENSIONS 6' x 16' x 14.0'
LOGGED BY D. McDonough
DEPTH WATER ENCOUNTERED 1/ Not Encountered DATE 6-17-86
DATE(S) LOGGED 6-17-86

CLASSIFICATION GROUP SYMBOL (describe sample taken)	CLASSIFICATION AND DESCRIPTION OF MATERIAL (Visual-Manual) SEE USBR 5000, 5005	% PLUS 3 in* (BY VOLUME) 3-5 in	5-12 in	PLUS 12 in
SC	0.0 to 4.0 ft. CLAYEY SAND WITH GRAVEL AND COBBLES (SC): About 65% fine to coarse, hard, subangular to subrounded sand; about 20% fines with low to medium plasticity, medium toughness, medium dry strength; about 15% predominantly fine, hard, subangular to subrounded gravel; strong reaction with HCl. Original field sample had a trace of hard, subangular to subrounded cobbles, with a maximum dimension of 200 mm. In-place conditions: moist, brown; gravel very mildly coated with $CaCO_3$; contains scattered lenses to 1 ft. in thickness of SANDY LEAN CLAY (CL); contains considerable roots to 1 ft.	T	T	
SP/SM	4.0 to 8.0 ft. POORLY GRADED SAND WITH SILT, GRAVEL, COBBLES AND BOULDERS (SP/SM): About 50% fine to coarse, hard, subangular to subrounded sand; about 40% fine to coarse, hard, subangular to subrounded gravel; about 10% nonplastic fines; weak reaction with HCl. Original field sample had about 5% 75 to 125 mm and 5% 125 to 300 mm hard, subangular to subrounded cobbles and about 5% hard, subangular to subrounded boulders, with a maximum dimension of 500 mm. In-place conditions: moist, light brown.	5	5	5
SP	8.0 to 14.0 ft. POORLY GRADED SAND WITH GRAVEL, COBBLES AND BOULDERS (SP): About 55% fine to coarse, hard, subangular to subrounded sand; about 40% predominantly fine, hard, subangular to subrounded gravel; about 5% nonplastic fines; weak reaction with HCl. Original field sample had about 5% 75 to 125 mm and a trace of 125 to 300 mm hard, subangular to subrounded cobbles and a trace of hard, subangular to subrounded boulders, with a maximum dimension of 400 mm. In-place conditions: moist, tan.	5	T	T

REMARKS: Easy to dig with backhoe. Considerable caving from 4 to 8 ft. Discontinued pit at 14.0 ft. - limit of equipment. Sparse prairie grass cover. Gravel and scattered cobbles on surface.

1/ Report to nearest 0.1 foot

*Estimated

GPO 849-366

7-1336-A (1-86)
Bureau of Reclamation

LOG OF TEST PIT OR AUGER HOLE

HOLE NO. TP86-3

FEATURE Glendo Dikes Seepage Control
PROJECT Pick-Sloan Missouri Basin Program
AREA DESIGNATION Borrow Area
GROUND ELEVATION 4713.1
COORDINATES N 48,129 E 34,457
METHOD OF EXPLORATION IHC 260 Backhoe
APPROXIMATE DIMENSIONS 5' x 15' x 13.5'
LOGGED BY
DEPTH WATER ENCOUNTERED 1/ Not Encountered DATE 6-17-86
DATE(S) LOGGED 6-17-86

CLASSIFICATION GROUP SYMBOL (describe sample taken)	CLASSIFICATION AND DESCRIPTION OF MATERIAL (Visual-Manual) SEE USBR 5000, 5005	% PLUS 3 in * (BY VOLUME) 3 - 5 in	5 - 12 in	PLUS 12 in
CL	0.0 to 7.0 ft. LEAN CLAY WITH SAND (CL): About 75% fines with low to medium plasticity, low to medium toughness, medium dry strength; about 20% predominantly fine sand; about 5% fine, hard, subangular to subrounded gravel; maximum size, 9.5 mm; strong reaction with HCl. In-place conditions: homogeneous, moist, brown. Considerable roots 0 to 1 ft. with scattered roots to 3 ft.			
SC	7.0 to 9.0 ft. CLAYEY SAND WITH GRAVEL AND COBBLES (SC): About 65% fine to coarse, hard, subangular to subrounded sand; about 20% fines with low to medium plasticity, medium toughness, medium dry strength; about 15% predominantly fine, hard, subangular to subrounded gravel; strong reaction with HCl. Original field sample had a trace of hard, subangular to subrounded cobbles, with a maximum dimension of 200 mm. In-place conditions: moist, brown; gravel very mildly coated with $CaCO_3$.	T	T	
SP/SM	9.0 to 13.5 ft. POORLY GRADED SAND WITH SILT, GRAVEL, COBBLES AND BOULDERS (SP/SM): About 50% fine to coarse, hard, subangular to subrounded sand; about 40% fine to coarse, hard, subangular to subrounded gravel; about 10% nonplastic fines; weak reaction with HCl. Original field sample had about 5% 75 to 125 mm and 5% 125 to 300 mm hard, subangular to subrounded cobbles and a trace of hard, subangular to subrounded boulders, with a maximum dimension of 400 mm. In-place conditions: moist, light brown.	5	5	T

REMARKS:

Easy to dig with backhoe. Discontinued pit at 13.5 ft. - limit of equipment. Sparse prairie grass and sagebrush cover. Scattered fine gravel on surface.

1/ Report to nearest 0.1 foot

*Estimated

7-1336-A (1-86) Bureau of Reclamation	LOG OF TEST PIT OR AUGER HOLE	HOLE NO. TP87-1

FEATURE Glendo Dam Dike No. 3
PROJECT P-SMBP, Oregon Trail Div., Glendo Un
AREA DESIGNATION Downstream toe
GROUND ELEVATION 4614± ft
COORDINATES N ______ E ______
METHOD OF EXPLORATION IHC 260A Backhoe
APPROXIMATE DIMENSIONS 10 X 22 ft
LOGGED BY D. McDonough
DEPTH WATER ENCOUNTERED 1/ Dry DATE 9/30/87
DATE(S) LOGGED 9/17/87

CLASSIFICATION GROUP SYMBOL (describe sample taken)	CLASSIFICATION AND DESCRIPTION OF MATERIAL SEE USBR 5000, 5005	% PLUS 3 in (BY VOLUME) 3-5 in	5-12 in	PLUS 12 in
GM in-place unit weight 10.7 ft	0.0 to 10.7 ft SILTY GRAVEL WITH COBBLES AND BOULDERS: About 45% fine to coarse, hard, subangular to subrounded gravel; about 40% fine to coarse, hard, subangular to subrounded sand; about 15% fines with no to low plasticity, no to low toughness; strong reaction with HCl. TOTAL SAMPLE (BY VOLUME): About 10% 3- to 5-inch hard, predominantly subrounded cobbles; about 5% 5- to 12-inch hard, predominantly subrounded cobbles; trace of hard, predominantly subrounded boulders; maximum dimension, 500 mm. IN-PLACE CONDITION: Moist, brown; contains a few pieces of weathered Brule siltstone to 8-inch size; contains layers of Lean Clay with Sand from 4 to 5 ft, 5.5 to 6.5 ft, and 9 to 10 ft. In-place wet unit weight of total sample from test at 9.5 to 10.5 ft: 142.0 lbf/ft^3	10	5	tr
CL in-place unit weight 17.3 ft	10.7 to 17.3 ft LEAN CLAY WITH SAND: About 85% fines with low plasticity, low to medium toughness; about 15% predominantly fine sand; maximum size, medium sand; strong reaction with HCl. IN-PLACE CONDITION: Hard, homogeneous, moist, grayish brown. In-place wet unit weight from test at 11.8 to 12.8 ft: 130.1 lbf/ft^3			

REMARKS: Pit located over centerline of railroad cut with north end of pit about 145 ft (horizontal distrance along railroad centerline) D/S of D/S edge of dike crest. Measuring point 15 ft D/S (south) of U/S end of pit. Pit stopped at 17.3 ft - limit of equipment. Pit backfilled upon completion.

1/ Report to nearest 0.1 foot

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